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THE EXPOSURE OF GUINEA PIGS TO
PRESSURE-PULSES GENERATED DURING
THE END-TO-END TEST (NO. 2) OF
ATLAS MISSILE 8-D (MARCH 31, 1962)

D. R. Richmond, Ph. D.

Technical Progress Report
on
Contract No. DA-49-146-XZ-055

This work, an aspect of investigations dealing with
the Biological Effects of Blast from Bombs, was
supported by the Defense Atomic Support Agency of
the Department of Defense

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Lovelace Foundation for Medical Education and Research
Albuquerque, New Mexico

June 26, 1962

FOREWORD

This report describes the effects on guinea pigs of the pressure-pulses emanating from a pressurized Atlas Missile ruptured during a safety test.

The data are limited to the pressure wave forms encountered and to the specific geometry of exposure. They are pertinent to military and industrial situations that involve safety measures about pressurized tanks.

This test was a small part of a continuing research program aimed at a better understanding of the human response to blast and shock phenomena.

ABSTRACT

To help determine the extent of the blast hazard to the operator of a Pressure Control Unit, an Atlas 8-D missile was pressurized to 35 psi with gaseous nitrogen and ruptured with an explosive charge. Three guinea pigs were placed on the Pressure Control Unit which was located beneath the ramp 90 ft from the missile. In addition, ten guinea pigs were placed on the surface of the simulated ramp at 30-, 35-, 75- and 94-ft ranges.

Following the burst, missile fragments littered the test area, although none were found at the Pressure Control Unit. Overpressures of only 0.3 psi were recorded in the vicinity of the Pressure Control Unit. The pressure pulse was slow rising (9-14 msec) and endured for about 25 msec. The three guinea pigs at that location were unharmed.

At the 30-ft ranges, pressures of 1.1-1.4 psi were recorded with times to peak and durations of 2-3 msec and 13-16 msec, respectively. One guinea pig's eardrum was ruptured, and one animal sustained a slight degree of lung hemorrhage. The other eight animals were unhurt. The biological results were discussed in relation to the pressure-time data.

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INTRODUCTION

Following transport of the Atlas missile, it is necessary that it be tested for leaks before fueling by pressurization of the upper "oxygen tank" and the lower "fuel tank" with gaseous nitrogen (GN₂). If the missile ruptures during pressurization, the operator of the Pressure Control Unit (located 90 ft away and below the ramp) could be subjected to blast hazards in the form of flying debris, translation and overpressure. These tests were therefore conducted to ascertain the extent of those hazards.

Test Number 1 was carried out 16 December 1961 with the Atlas Missile 8-D. The lower fuel tank was pressurized with GN₂ to 60 psi and the upper oxygen tank to 30 psi. A 30.06-rifle bullet was fired through the oxygen tank to initiate rupture. The missile did not burst, but rather, the gas leaked from the oxygen tank through the entrance and exit bullet holes. The bulk-head between tanks failed, and the gas in the fuel tank vented to the outside via the oxygen tank and bullet holes. Except for the bullet holes in the upper tank and the ruptured bulk-head, the missile remained intact.

On Test Number 2, the same missile 8-D was employed. The bullet holes were patched, but not the bulk-head; consequently, the missile was essentially a single tank. The plans were to pressurize the entire missile to 35 psi with GN₂ which would provide the same gaseous content as with Test Number 1. Rupture was to be initiated by a sheet of plastic explosive (Dupont Sheet Explosive EL 506 A4) that had an explosive yield equivalent to 1 lb of TNT. The explosive was on the north side of the missile at the level of the bulk-head.

On Test Number 2, it was decided that personnel from the Lovelace Foundation (with the approval of Colonel Robert H. Holmes, Project Officer, Defense Atomic Support Agency, Department of Defense -- Contract DA-49-146-XZ-055) would place guinea pigs at various distances from the missile in the Pressure Control Unit room to supplement the pressure-time gauges. In the past, experimental animals have been employed with great advantage in assessing the total environment near explosive phenomena¹⁻³.

METHODS

A total of 15 guinea pigs of both sexes and with an average body weight of 258.7 grams (234.4-298.6) were employed. Ten animals were exposed at ground level, three were placed on the Pressure Control Unit and two were kept for controls. During the test, all animals were held in place by 3-1/2 x 8-in. cylindrical cages made of "chicken wire." The cages and animals were all secured side-on with respect to the missile. Animals could turn end-for-end in their cages.

The general layout of the animal placement can be seen in Figures 1 and 2. Guinea pigs numbered "1", "2", "3" and "4" were respectively on the west, north, east and south sides of the missile--all at the 30-ft range. Also, to the south were animals numbered "5" and "6" at 35 ft; "7" and "8" at 75 ft; and "9" and "10" at the 94-ft ranges. Below the ramp, animal "11" was on top of the Pressure Control Unit, while animals "12" and "13" were on the operator's side of this unit.

The locations of the eleven pressure transducers (Wiancko Model P-1409) can be seen in Figures 1 and 2. Gauges (Boss) numbered 1 through 5 were in the Pressure Control Unit room beneath the ramp; gauge 6 was on the simulated ramp; and gauges 7 through 10 were on the surface 30 ft from the missile's center--one to the south, north, east and west, respectively. Gauge 31 was located on the missile.

PLAN VIEW
OF TEST AREA
SHOWING BOSS LOCATIONS
AND TEST SPECIMEN

2

Boss 10

ANIMALS
MISSILE
PLCS.
TYP.
30-0

Diagram illustrating the locations of the four bosses and the missile relative to the Instrumentation Station (Animal 5). The Instrumentation Station is at the top right. Boss 1 is to its left. Boss 2 is below the Instrumentation Station. Boss 3 is to the left of Boss 2. Boss 4 is to the left of Boss 3. The missile is located below the Instrumentation Station, to the right of Boss 2.

DIRECTION TEST TIME OF FEELING WIMMELIAG.

PLAN VIEW NOT TO SCALE

NOT TO SCALE

A hand-drawn diagram of a game map, likely from Super Mario Bros. 3. The map shows a level layout with various entities labeled. Key features include:

- RAMP WALL:** A horizontal line labeled "RAMP WALL" at the top.
- RAMP ROOF:** A line labeled "RAMP ROOF" on the left.
- BOSS 4 (BOSS ROOF):** A small circle labeled "BOSS 4 (BOSS ROOF)" near the top center.
- BOSS 5:** A small circle labeled "BOSS 5" near the center.
- BOSS 6:** A small circle labeled "BOSS 6" near the bottom center.
- BOSS 7:** A small circle labeled "BOSS 7" near the bottom center.
- BOSS 8:** A small circle labeled "BOSS 8" near the bottom center.
- BOSS 9:** A small circle labeled "BOSS 9" near the bottom center.
- ANIMAL 1 (low score):** A small circle labeled "ANIMAL 1 (low score)" near the bottom center.
- ANIMAL 2 (low score):** A small circle labeled "ANIMAL 2 (low score)" near the bottom center.
- ANIMAL 3 (low score):** A small circle labeled "ANIMAL 3 (low score)" near the bottom center.
- ANIMAL 4 (low score):** A small circle labeled "ANIMAL 4 (low score)" near the bottom center.
- ANIMAL 5 (low score):** A small circle labeled "ANIMAL 5 (low score)" near the bottom center.
- ANIMAL 6 (low score):** A small circle labeled "ANIMAL 6 (low score)" near the bottom center.
- ANIMAL 7 (low score):** A small circle labeled "ANIMAL 7 (low score)" near the bottom center.
- ANIMAL 8 (low score):** A small circle labeled "ANIMAL 8 (low score)" near the bottom center.
- ANIMAL 9 (low score):** A small circle labeled "ANIMAL 9 (low score)" near the bottom center.
- ANIMAL 10 (low score):** A small circle labeled "ANIMAL 10 (low score)" near the top center.
- ANIMAL 11 (low score):** A small circle labeled "ANIMAL 11 (low score)" near the bottom center.
- ANIMAL 12 (low score):** A small circle labeled "ANIMAL 12 (low score)" near the top center.
- DUMMY 3:** A small circle labeled "DUMMY 3" near the center.
- DUMMY 4:** A small circle labeled "DUMMY 4" near the center.
- DUMMY 5:** A small circle labeled "DUMMY 5" near the center.
- DUMMY 6:** A small circle labeled "DUMMY 6" near the center.
- DUMMY 7:** A small circle labeled "DUMMY 7" near the center.
- DUMMY 8:** A small circle labeled "DUMMY 8" near the center.
- DUMMY 9:** A small circle labeled "DUMMY 9" near the center.
- DUMMY 10:** A small circle labeled "DUMMY 10" near the center.
- DUMMY 11:** A small circle labeled "DUMMY 11" near the center.
- DUMMY 12:** A small circle labeled "DUMMY 12" near the center.
- DUMMY 13:** A small circle labeled "DUMMY 13" near the center.

NOTE:  INDICATES PRESSURE TRANSDUCER (BLAST) WITH ARROW INDICATING DIRECTION TRANSDUCER FACES.

 INDICATES PRESSURE TRANSDUCER (BLAST) FACING OUT OF PAGE.

 INDICATES A GUINEA PIG.

Figure 1

RESULTS AND DISCUSSION

Recovery of the guinea pigs began about five minutes after the missile ruptured. All cages and animals were found intact; although some narrowly missed being struck with falling missile debris that was found in close proximity to the cages at the 30- and 35-ft ranges. All animals survived the test and externally appeared alert and uninjured.

At thirty minutes following the test, autopsy of the experimental animals was undertaken. They were sacrificed with intraperitoneal injections of Nembutal. Table 1 lists the findings at autopsy. Except for the eardrum rupture in animal "2" (which was located 30 ft to the north of the missile) and a slight degree of lung hemorrhage sustained by animal "6" (at the 35-ft range), the findings were negative.

That the pressure-pulse from the bursting missile was not intense enough to cause significant animal injury or lethality was substantiated by the pressure-time records which are illustrated in Figures 3 and 4. The significant pressure-time parameters were picked from these records and appear in Table 2.

According to the records in Figure 3, the pressure-time pattern in the Pressure Control Unit room was merely a compression wave and not a shock wave. The pressures from the record of gauge 3 appeared low compared to the other four gauges in the Pressure Control Unit, which showed a P_{max} of 0.33 to 0.35 psi with rise times of from 10.2 to 14.3 msec, with minimum pressures during the negative phase of -0.33 to -0.50 psi.

It is of interest to note from the four pressure-time records shown in Figure 4, taken with gauges at the 30-ft ranges, that the pressure disturbance arrived at the gauge to the north of the missile about 2.5 msec before it arrived at those located to the east and west, and about 4.5 msec before it reached the gauge placed 30 ft to the south. Apparently, the shock wave from the high-explosive detonation reached these gauges just before the main pulse from the rupturing missile. In addition, the rupture was initiated along the north side of the missile on which the explosive was attached. Gauge 31, located on the missile, showed that the pressure in the tank started to decay 8 msec after detonation and reached zero pressure in the next 9 msec.

The pressure-time record taken with the gauge on the top of the ramp at the 94-ft range showed a P_{max} of 0.81 psi and a duration of 12.9 msec. The time to P_{max} was about 1 msec. Unfortunately, because of the relatively slow frequency response of the gauges and recording system, one cannot tell whether or not there was a shock front present at the leading edge of the pulse.

TABLE 1

BIOLOGICAL DATA FROM GUINEA PIGS EXPOSED
TO THE AIR BLAST FROM ATLAS MISSILE 8-D

Animal Number	Approximate Range* ft	Body Weight, gm	Lung Weight, gm	% of Body Weight	Lung Weight, % of Body Weight	Remarks
1	30	298.6	2.2	0.74		
2		243.8	2.0	0.82		
3		290.0	2.2	0.76		
4		234.4	1.9	0.81		
	Average		2.1		0.78	
5	35	275.9	2.2	0.80		
6		250.0	2.2	0.88		
	Average		2.2		0.84	
7	75	259.0	1.9	0.73		
8		275.5	2.0	0.72		
	Average		2.0		0.72	
9 _a	94	235.9	1.9	0.80		
10		293.4	2.2	0.75		
	Average		2.0		0.78	
11	89	245.0	1.8	0.73		
12		198.2	1.5	0.76		
13		285.1	2.0	0.70		
	Average		1.8		0.73	
Control:						
A		257.5	1.8	0.70		
B		237.9	2.0	0.84		
	Average		1.9		0.77	

*Measured to the center of the missile (ground range).

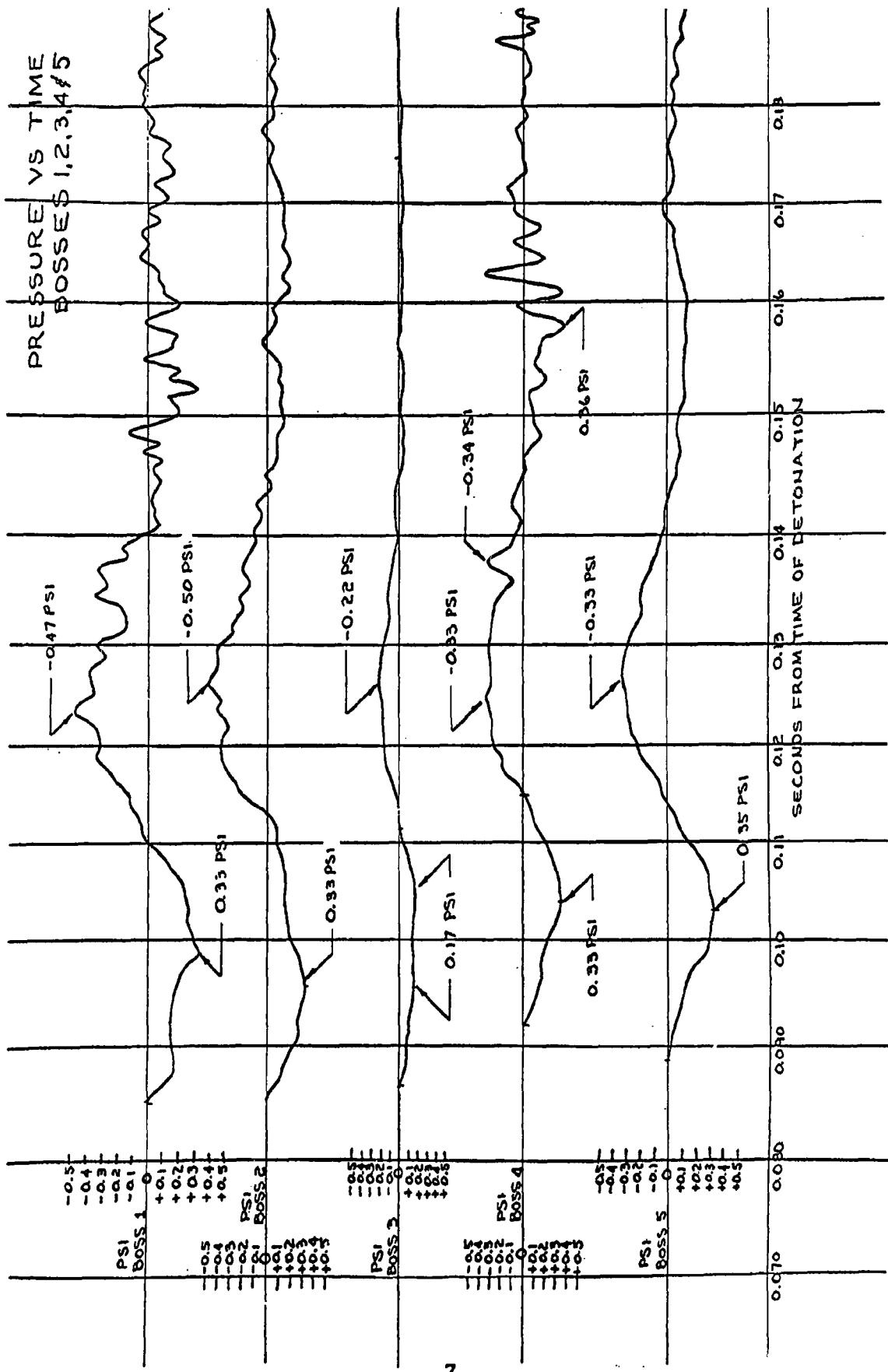


Figure 3

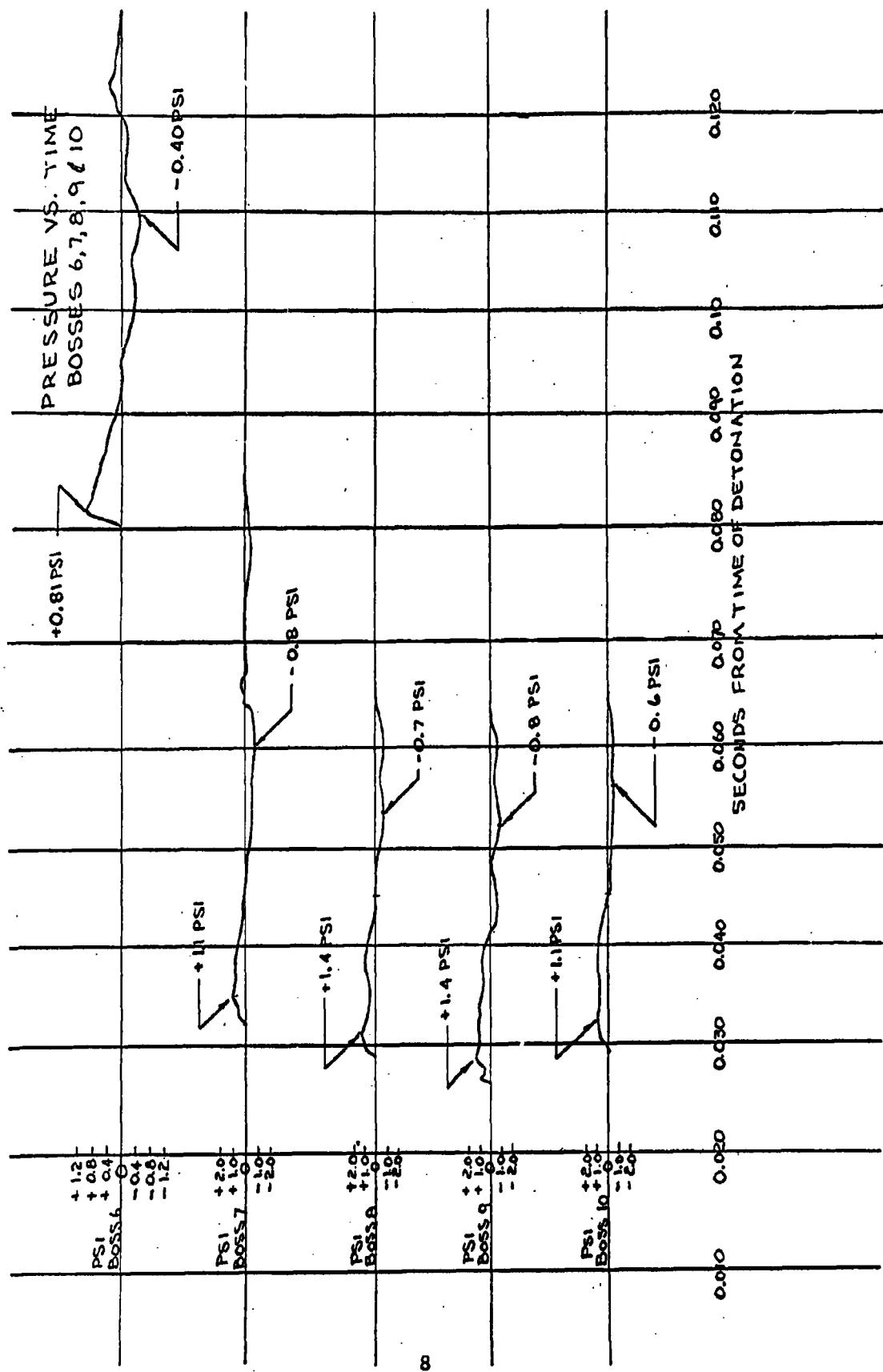


Figure 4

TABLE 2
SUMMARY OF THE PRESSURE-TIME PARAMETERS

Gauge No.	Location	P _{max} , psi	Time to P _{max} , msec	Duration Positive Phase, msec	Minimum Negative Pressure, psi	Time to Minimum Negative Pressure, msec
1	Top of PCU	0.33	13.8	25.1	-0.47	13.4
2	Back of PCU, opposite dummy	0.33	10.2	27.7	-0.50	13.1
3	Left side of PCU	0.17	9.1	25.1	-0.22	14.8
4	Wall back of dummy	0.33	11.9	22.8	-0.33	9.8
5	Wall to the right of the dummy	0.35	14.3	25.3	-0.33	12.6
6	On the top of the simulated ramp	0.81	1.3	12.9	-0.40	16.3
7	30 ft to the south of the missile	1.1	2.9	13.1	-0.80	15.4
8	30 ft to the west of the missile	1.4	2.2	16.1	-0.70	8.6
9	30 ft to the north of the missile	1.4	2.3	15.0	-0.80	11.0
10	30 ft to the east of the missile	1.1	3.2	16.1	-0.60	10.8

*Measured from the end of the positive phase.

The pressure required to rupture 50 percent of guinea pig eardrums has been reported to be 7.4 psi³. Thus, one may expect an occasional eardrum to fail at the 1.4-psi level as experienced on this test. On the other hand, it is doubtful that the slight degree of lung hemorrhage sustained by animal "6" was caused by the magnitude of overpressure encountered. Shock tube studies with guinea pigs in the 400 to 500 gram weight range suggest the threshold for pulmonary hemorrhage to be near 15 psi⁴. The lung injury may have been caused by debris striking the animal. There were no missile fragments found in the vicinity of the Pressure Control Unit.

Data on the gas temperature in the missile, the acceleration measurements taken on the anthropomorphic dummy seated at the Pressure Control Unit, sound-intensity levels and the like may be found in the main test report⁵.

SUMMARY

1. This test was undertaken to assess the blast hazards in the vicinity of a man stationed at a Pressure Control Unit located beneath the ramp approximately 90 ft from an Atlas 8-D missile during its pressurization check-out prior to fueling.
2. The Atlas Missile 8-D, without the bulk-head between its liquid oxygen and fuel tanks, was pressurized to 35 psi with gaseous nitrogen and ruptured with a small, high-explosive charge.
3. To supplement pressure-time gauges, thirteen guinea pigs were exposed to the pressure-pulse produced by the bursting missile. Three animals were placed on the Pressure Control Unit. On the ramp, four animals were located at 30 ft, and 2 each at 35-, 75- and 94-ft ranges.
4. All animals survived the test. Except for a ruptured eardrum in one of the four animals at the 30-ft range and a slight degree of lung hemorrhage in a guinea pig at the 35-ft range, the findings at autopsy were negative.
5. The maximum overpressure recorded in the vicinity of the Pressure Control Unit was 0.35 psi. The pressure was slow rising with a time to peak of 14 msec, and the duration of the positive phase was 25 msec.
6. On the simulated ramp at the 30-ft range, overpressures of 1.1-1.4 psi were recorded. The pressures peaked in 2-3 msec and endured for 13-16 msec at that distance from the missile.
7. The biological results were discussed briefly in connection with the pressure-time data.

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